A Preliminary Evaluation of Road Deicing Chemical Concentrations in North Idaho Streams Adjacent to Interstate 90 That Drain Fourth of July Pass

Addendum: An Analysis of Data Collected from December 2009 through June 2011

State of Idaho
Department of Environmental Quality

February 2012

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1 Introduction

This report presents data collected by the Idaho Department of Environmental Quality (DEQ) adjacent to Interstate 90 (I-90) in northern Idaho as part of an effort to determine instream concentrations of road deicing chemicals. DEQ began investigating road deicing (salt) chemical concentrations in two streams adjacent to I-90 in 2008 (DEQ 2008a). Cedar and Fourth of July Creeks drain the west and east sides of Fourth of July Pass, respectively (Figure 1). This addendum updates this effort with data collected from December 2009 through June 2011.

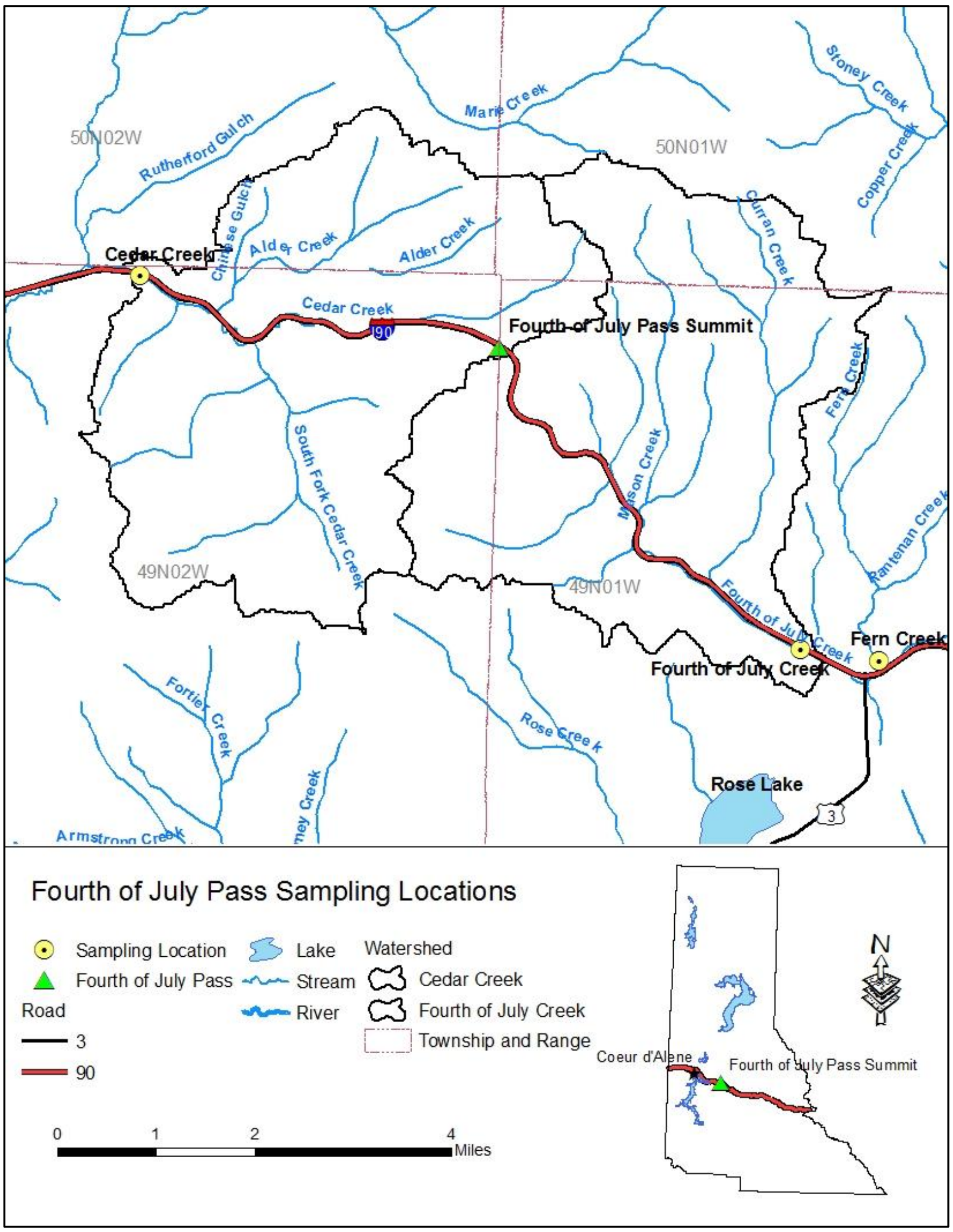


Figure 1. Fourth of July Pass sampling locations.

The original monitoring camping in 2008 was triggered because of the expanded use of road salt by the Idaho Transportation Department (ITD) as the preferred method for improved winter driving conditions. Increased needle browning, tree die-off along the roadway, and calls from concerned citizens added to the justification for the original monitoring effort.

During 2008, two pieces of monitoring equipment were deployed to continuously monitor instream conductivity in Cedar and Fourth of July Creeks. Water samples were collected twice monthly from February through June. Water samples were also collected from Fern Creek, and conductivity was measured using a handheld conductivity meter to determine the background (nonimpacted) water quality condition. Fern Creek was used as a control stream because it is not impacted by runoff from I-90 (Figure 1). Data collected showed a strong relationship between road salt (sodium chloride, or NaCl) and specific conductivity in Cedar and Fourth of July Creeks.

DEQ shared results with the ITD following the initial 2008 monitoring effort, and a partnership between DEQ and ITD was formed to continue monitoring through June 2011. ITD purchased four data loggers capable of continuously monitoring specific conductivity, water temperature, and stream stage (height). Three data loggers were deployed and one was used as a backup. The loggers were deployed in the same Cedar, Fourth of July, and Fern Creek locations monitored in 2008. The new data loggers are easier to deploy and conceal, record stream stage, and stay calibrated for a longer period. They are also much cheaper than the previous equipment used. ITD also paid for all lab analysis. DEQ deployed and retrieved the data loggers, collected water samples, measured streamflow, and wrote this report. Without the partnership between DEQ and ITD, it would not have been possible to continue this study. For more information about ITD's winter road treatment operations, see Appendix A.

2 Monitoring Results

Water samples and streamflow data were collected within Cedar and Fourth of July Creeks during ten field visits and within Fern Creek on seven different occasions. During each visit, data collected by the data logger were downloaded, and loggers were inspected for vandalism and/or damage. Water samples were collected from the center of the channel and depth integrated (DEQ 2008b). Water samples were then placed in a cooler and transported to the lab for analysis. Each sample was analyzed for calcium (Ca), magnesium (Mg), sodium (Na), and chloride (Cl)—all measured in milligrams per liter (mg/L) (Table 1). Sodium and chloride are the ions that make up road salt. Magnesium and calcium are used in a variety of road deicing chemicals.

Table 1. Lab results.

Date	Time	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	Cl (mg/L)
Cedar Creek					
12/22/2009	9:30	9.30	3.23	23.6	46.8
1/13/2010	12:10	8.84	3.06	26.1	49.5
2/10/2010	12:40	5.44	1.97	11.8	17.1
3/29/2010	12:55	4.71	1.80	7.12	9.54
4/28/2010	10:45	4.06	1.50	5.86	7.17
6/9/2010	11:20	3.62	1.36	4.34	3.53
7/22/2010	10:40	5.74	1.87	6.16	7.06
9/30/2010	10:00	7.28	2.38	8.60	11.4
12/22/2010	11:40	4.72	1.76	8.54	12.6
2/2/2011	11:00	3.46	1.38	5.33	7.39
Fourth of July Creek					
12/22/2009	10:15	8.05	2.96	29.0	59.7
1/13/2010	10:15	6.35	2.31	24.5	44.4
2/10/2010	11:00	4.59	1.76	13.1	20.6
3/29/2010	11:55	3.89	1.56	8.93	12.1
4/28/2010	9:45	3.21	1.19	7.17	10.0
6/9/2010	9:30	2.89	1.09	4.81	4.78
7/22/2010	9:00	4.45	1.53	7.07	9.52
9/30/2010	9:20	5.83	2.10	11.7	18.6
12/22/2010	10:15	3.92	1.50	9.42	16.8
2/2/2011	9:30	2.85	1.13	6.69	10.4
Fern Creek					
1/13/2010	11:27	3.24	1.22	2.54	0.868
3/29/2010	12:30	2.97	1.20	2.00	0.488
4/28/2010	10:20	2.75	1.05	2.06	0.568
6/9/2010	10:00	3.18	1.24	2.22	0.614
7/22/2010	9:30	3.20	1.17	2.33	0.440
12/22/2010	10:50	3.54	1.40	2.58	0.849
2/2/2011	10:00	2.55	1.06	2.08	0.602

2.1 Regression Analysis

As discussed in the 2008 report, a regression analysis between each of the ions (Na, Cl, Ca, and Mg) and specific conductivity (measured in microsiemens per centimeter, or µS/cm) was completed for the samples collected from December 2009 through February 2011. The regression analysis allows for the determination of sodium and chloride concentrations during the entire period the data logger was deployed and specific conductivity was recorded (Figure 2–4).

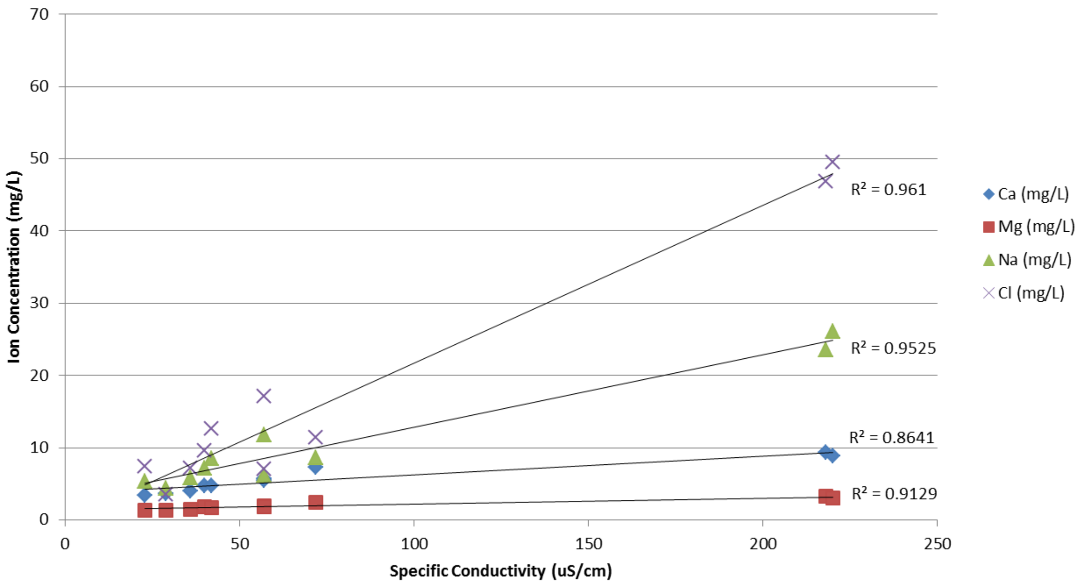


Figure 2. Cedar Creek regression analysis.

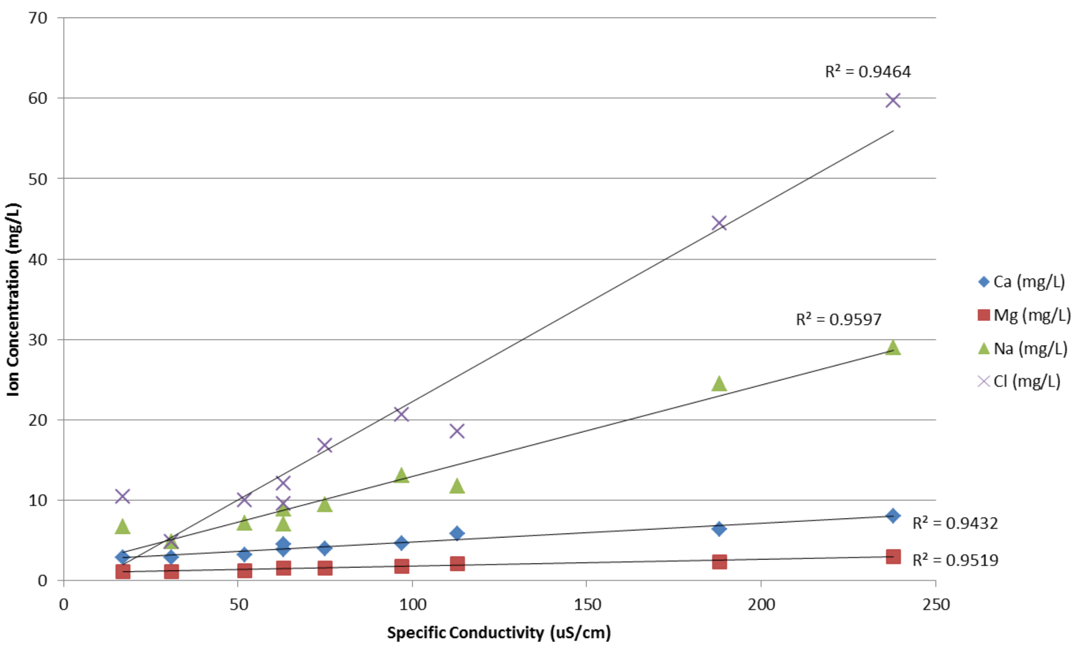


Figure 3. Fourth of July Creek regression analysis.

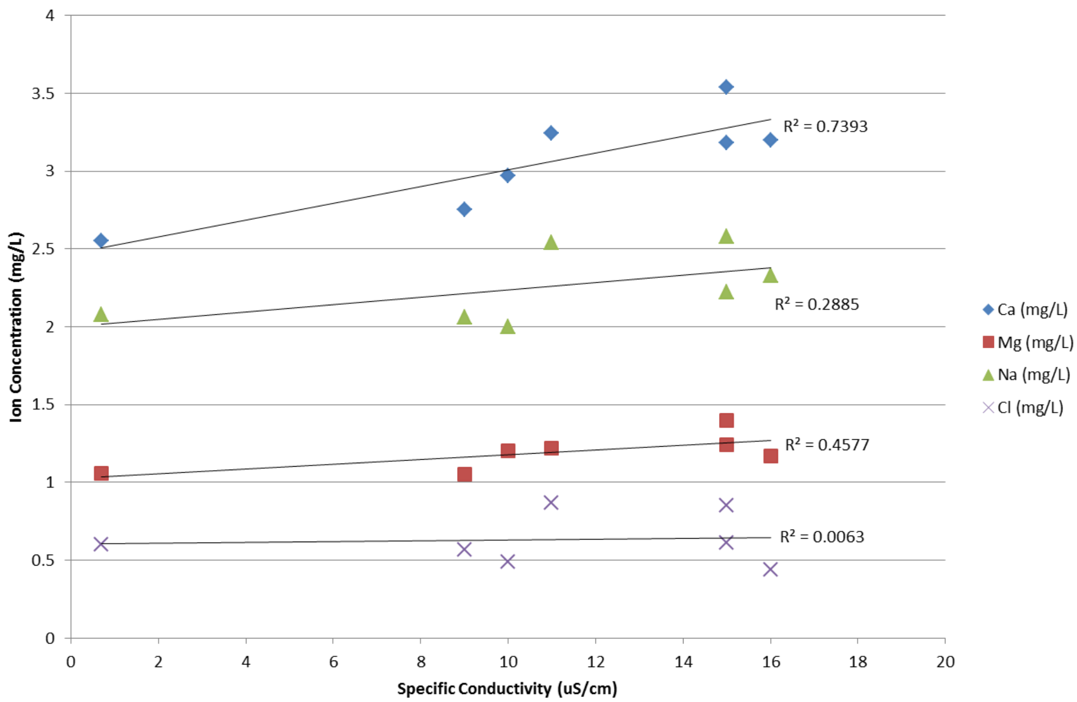


Figure 4. Fern Creek regression analysis.

A strong correlation between ion concentrations and specific conductivity allows for confidence when calculating ion concentration from measured specific conductivity. The following equations (Table 2) result from the regression analysis. The R^2 value provides a measure of how well future outcomes can be predicted by the equation. An R^2 value of 1 represents an equation that can exactly predict the outcome. The correlation between sodium and chloride and conductivity is strong in streams impacted by road salt (Cedar and Fourth of July Creeks) and low in streams not impacted by road salt (Fern Creek) (Table 2).

Table 2. Regression equations and R^2 values generated from Cedar, Fourth of July, and Fern Creeks.

Cedar Creek		
Sodium	$y = 0.1008x + 2.7393$	$R^2 = 0.9525$
Chloride	$y = 0.2188x - 0.1606$	$R^2 = 0.9610$
Fourth of July Creek		
Sodium	$y = 0.1135x + 1.5999$	$R^2 = 0.9597$
Chloride	$y = 0.2446x - 2.2328$	$R^2 = 0.9464$
Fern Creek		
Sodium	$y = 0.0237x + 1.9989$	$R^2 = 0.2885$
Chloride	$y = 0.0025x + 0.6055$	$R^2 = 0.0063$

Note: y = calculated ion concentration (mg/L)
x = measured specific conductivity (µS/cm)

Magnesium and calcium were also analyzed in this study and as part of the 2008 monitoring effort because magnesium and calcium are ions used in a variety of road deicing chemicals. A strong correlation also exists between these two ions and specific conductivity. Although the focus of this study is sodium and chloride because they are the components of the deicing agent being applied to the roadway, continued monitoring of magnesium and calcium will hypothetically show any changes in water or soil chemistry or changes in road deicing chemicals. See the 2008 report for a discussion on how road salt can alter the chemistry of soil (DEQ 2008a).

Specific conductivity spikes during the winter driving season in response to road salt application (Figure 5). Specific conductivity then recedes following application. Specific conductivity is lowest during the early summer months when stream runoff is still fairly high, most of the deicing chemicals have been flushed from the system, and ground water recharge is not a dominate component of stream discharge. Specific conductivity begins to rise again in the late summer and early fall as the majority of the streamflow consists of ground water recharge. This phenomenon is common and has been observed in other northern Idaho streams.

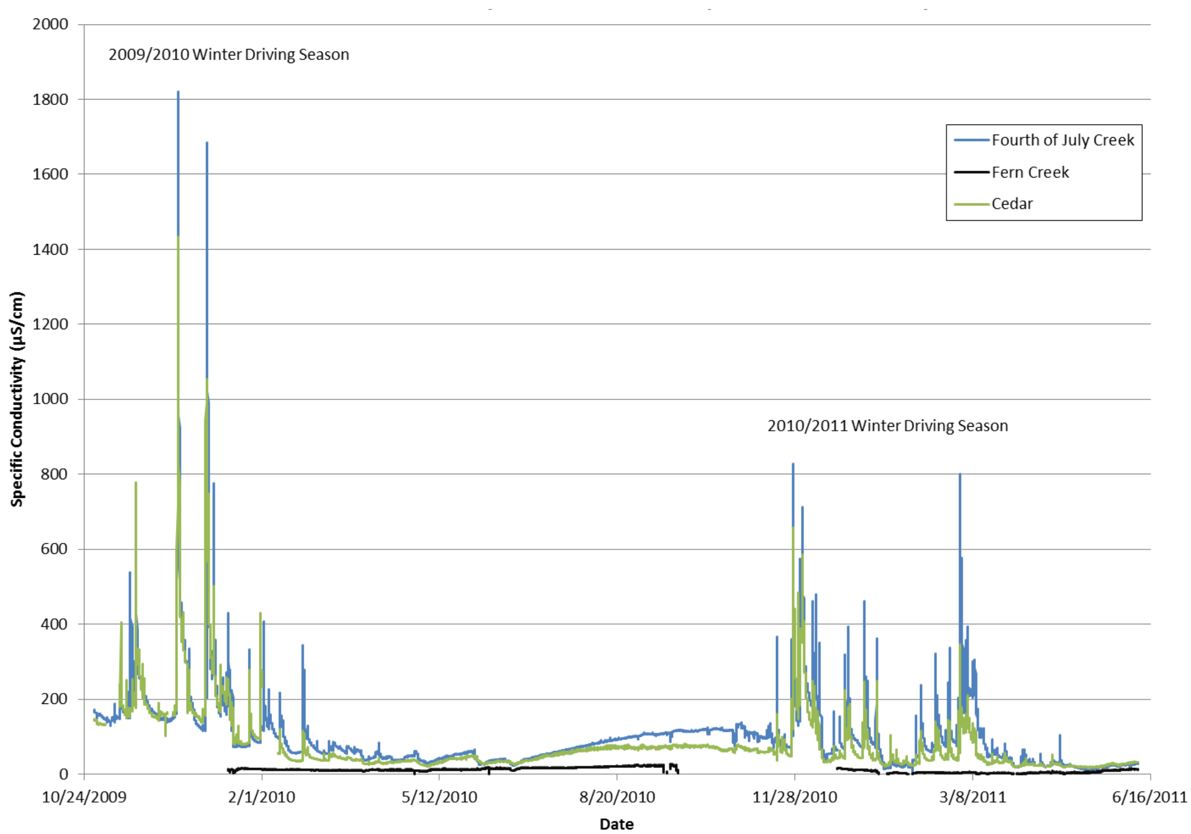


Figure 5. Cedar, Fourth of July, and Fern Creek specific conductivity.

Road salt concentrations can be calculated for Cedar and Fourth of July Creeks (Figure 6 and 7) using the equations developed from the regression analysis and the measured specific conductivity (Table 2 and Figure 5). Fourth of July Creek has consistently (2008 study and current data) exhibited higher concentrations of sodium and chloride than Cedar Creek. Two factors may account for these higher concentrations:

- A greater percentage of I-90 is within the Fourth of July Creek watershed.
- A larger majority of the stream is located adjacent to the interstate when compared to Cedar Creek.

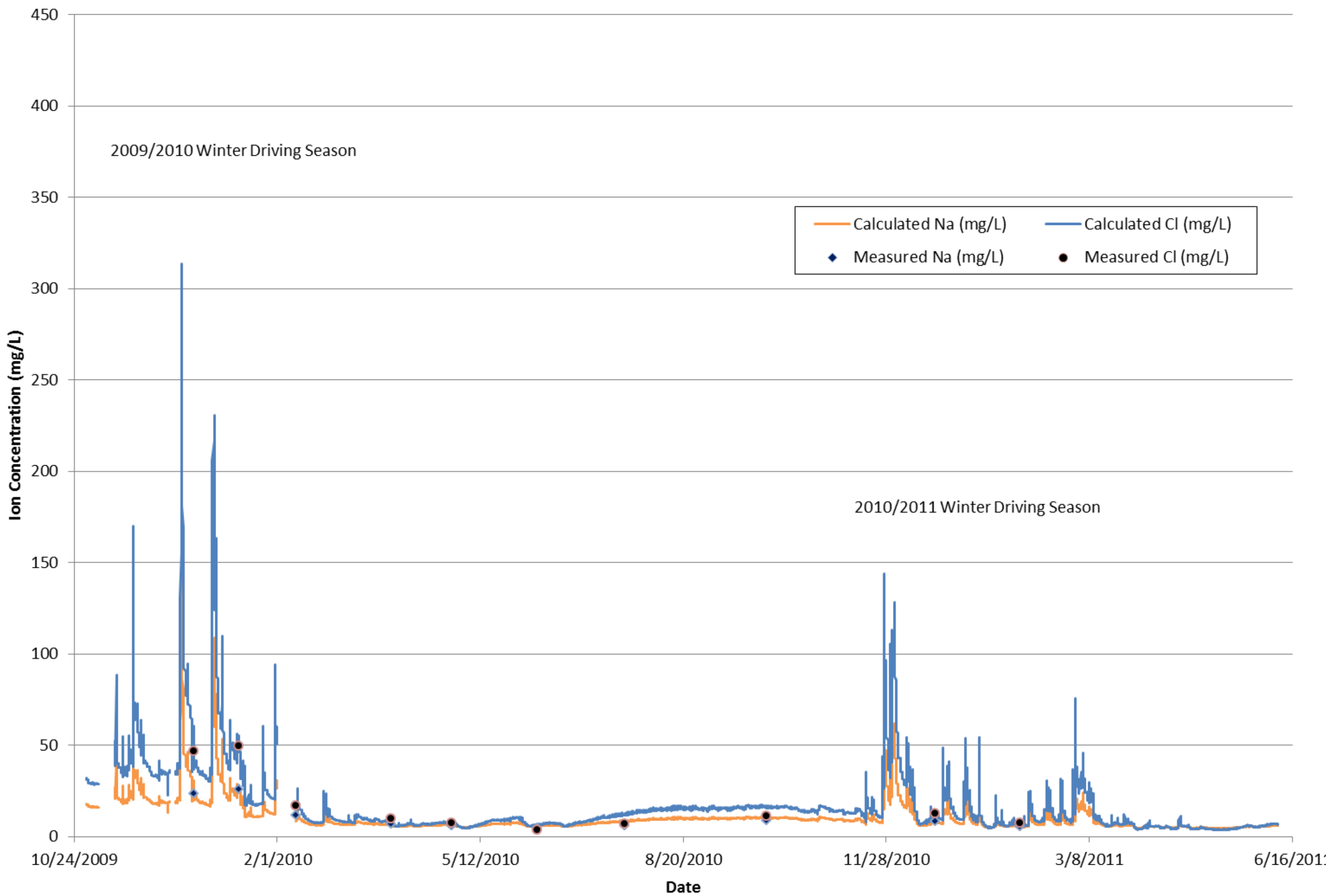


Figure 6. Cedar Creek sodium and chloride calculated and measured concentrations.

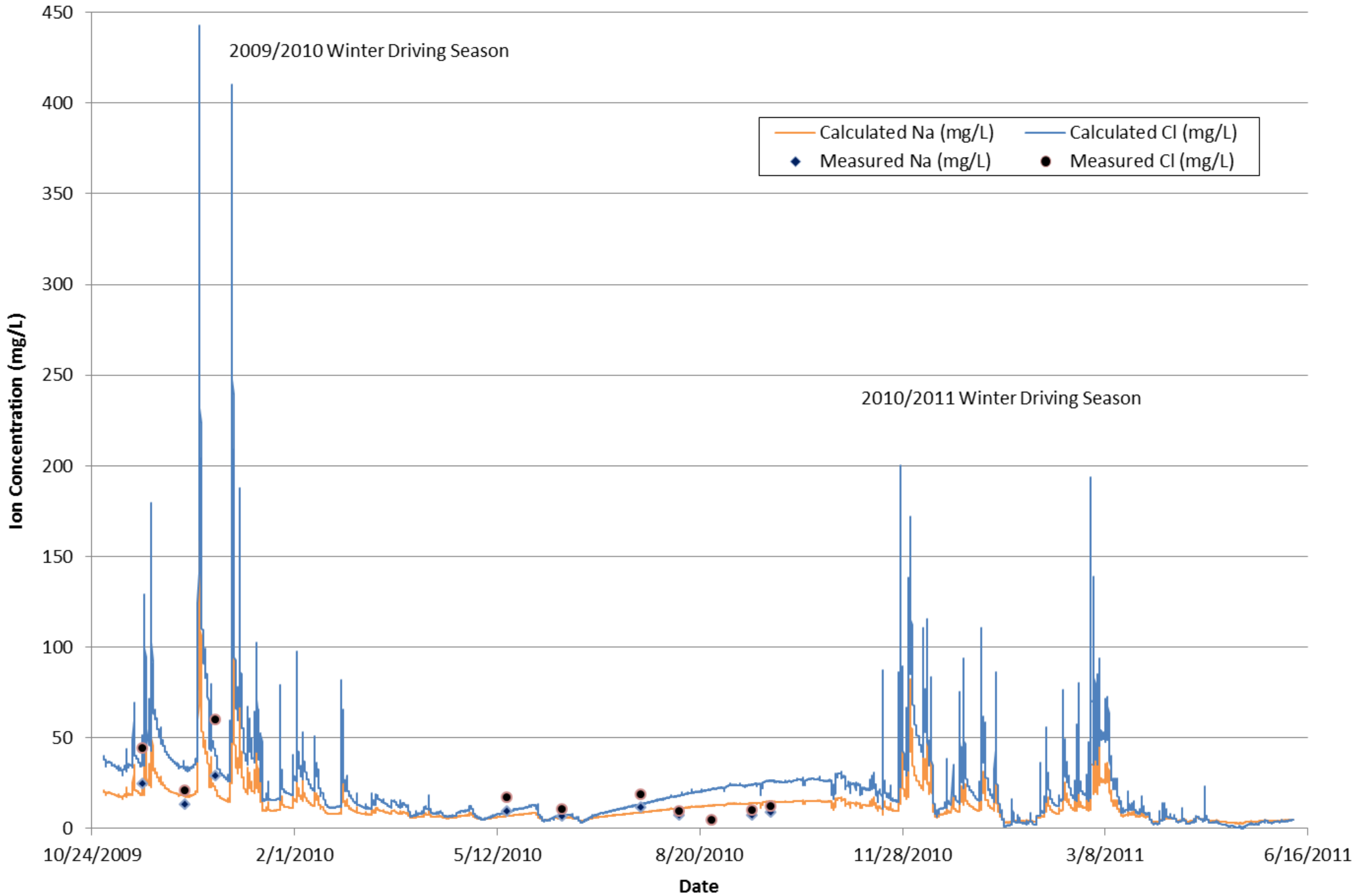


Figure 7. Fourth of July Creek sodium and chloride calculated and measured concentrations.

Sodium and chloride concentrations spike during the winter driving season and remain relatively constant during other parts of the year. The highest concentration of both sodium and chloride occurred during the 2009/2010 winter driving season (Table 3). The 2009/2010 winter was the least snowy of the three winter driving seasons monitored. Although the roadway may not have experienced as much snowfall during the 2009/2010 season, road salt was still applied to prevent ice and maintain traction. The relative lack of snow may account for less dilution of the road salt and result in high concentrations.

Table 3. Maximum calculated ion concentration comparison.

Winter Driving Season	Sodium (mg/L)	Chloride (mg/L)	Conductivity (µS/cm)
Cedar Creek			
2008–2009[a]	35	68	292
2009–2010	147	314	1,435
2010–2011	69	144	658
Fourth of July Creek			
2008–2009[a]	58	112	471
2009–2010	208	443	1,820
2010–2011	96	200	827

Note: 2008–2009 season data from DEQ 2008a

The chemical make-up of road salt (NaCl) lends itself well to analyzing only one ion when road salt is applied to the roadway. Knowing one ion concentration could be used to determine the concentration of the other during the time of the year when road salt is applied to the roadway and is present in nearby streams (Figure 8). During the nonwinter driving season, sodium and chloride occur in lower concentrations and the regression analysis is weaker (R^2 value less than winter driving ratios) (Figure 8). The data displayed in Figure 8 are a compilation of all data collected during the 3-year study. The data were collected from February through June 2008 and December 2009 through February 2011.

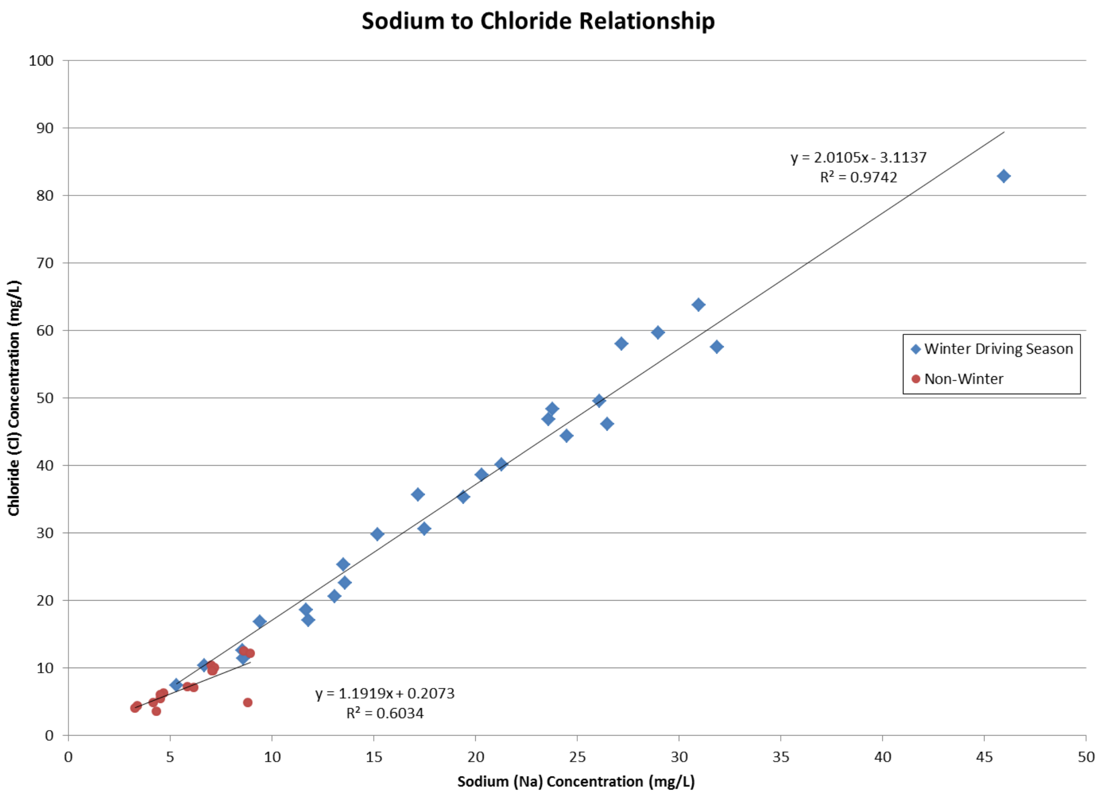


Figure 8. Sodium to chloride relationship.

The ratio of sodium and chloride concentrations of samples taken during the winter driving season indicates that road salt (NaCl) is the likely source of sodium and chloride (Figure 9). One gram of road salt contains approximately 40% sodium and 60% chloride, the same ratio observed in winter water samples. The sodium chloride ratios shift in Fern Creek, the control stream not impacted by highway runoff. Sodium is the dominate ion in Fern Creek, and the average ratio of sodium to chloride is 3:1. The ratios of sodium and chloride shift as road salt is carried through the system and the stream is not influenced by road salt, but the sodium chloride ratio remains higher in Cedar and Fourth of July Creeks relative to Fern Creek.

The remaining elevated levels of sodium and chloride during the nonwinter season may be attributed to road salt remaining in the watershed and/or a higher background level of the ions in the watershed. The Cedar and Fourth of July Creek watersheds are significantly larger than the Fern Creek watershed. The larger watershed may result in an increased natural level of sodium and chloride.

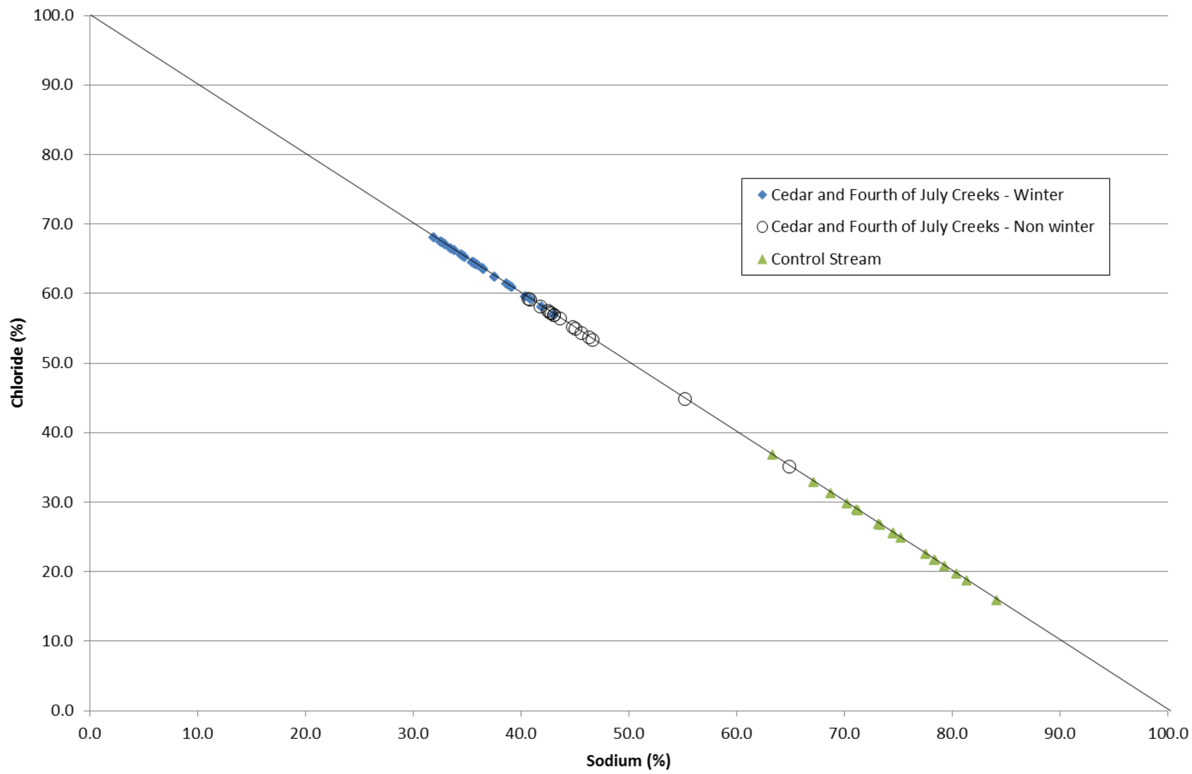
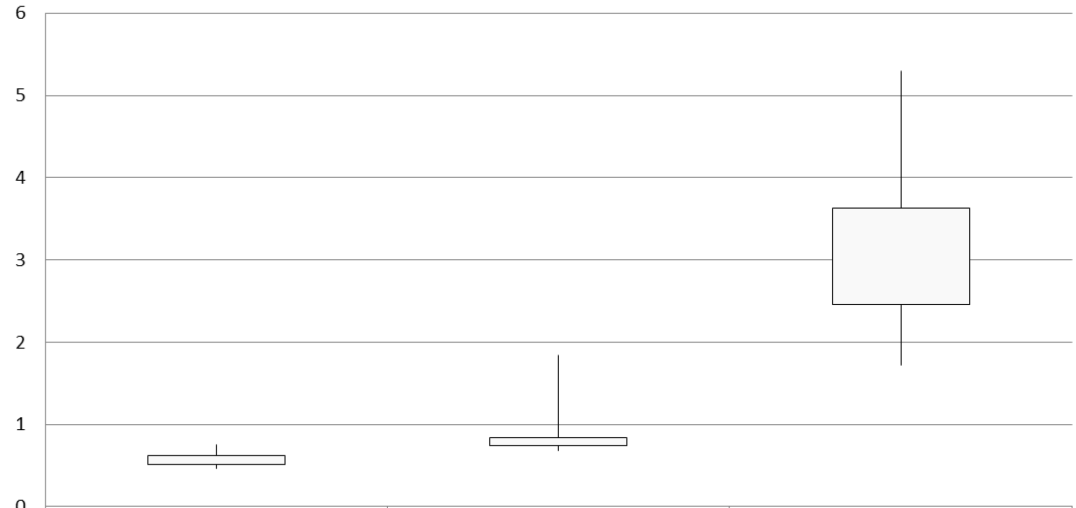


Figure 9. Sodium chloride ratios for samples collected in Cedar, Fourth of July, and Fern Creeks.

The sodium chloride concentration ratios varied between samples collected during the winter driving season, the nonwinter driving season, and the control stream (Figure 10). The ratios of sodium to chloride during the winter driving season were below 1 (Na:Cl < 1). The ratio of sodium to chloride during the nonwinter driving season was generally below 1 with a maximum of 1.8. All other statistics calculated during the nonwinter driving season were greater than samples collected during the winter driving season and less than those collected from the control stream (Na:Cl < 1 but > winter samples). The ratio of sodium to chloride shifts above 1 for all samples collected from the control stream, suggesting a water chemistry change between the experimental and control streams (Na:Cl > 1). The sodium chloride ratios of water samples collected during the nonwinter driving season suggest that sodium chloride from road salt may be altering water chemistry throughout the year.



	Winter	Non-Winter	Control Stream
q1	0.51	0.74	2.46
min	0.47	0.68	1.72
max	0.75	1.84	5.30
q3	0.62	0.84	3.63

Figure 10. Sodium chloride concentration ratios during the winter and nonwinter driving season and control stream.

2.2 Steamflow

Streamflow (i.e., discharge) was measured during each field visit to develop a relationship between stream stage (height recorded by data logger) and streamflow (measured in cubic feet per second, or cfs) (Figures 11–13). Developing this relationship allows for a detailed stream discharge record by converting stream stage to stream discharge. Knowing the stream discharge then allows for a determination of road salt loads within Cedar and Fourth of July Creeks.

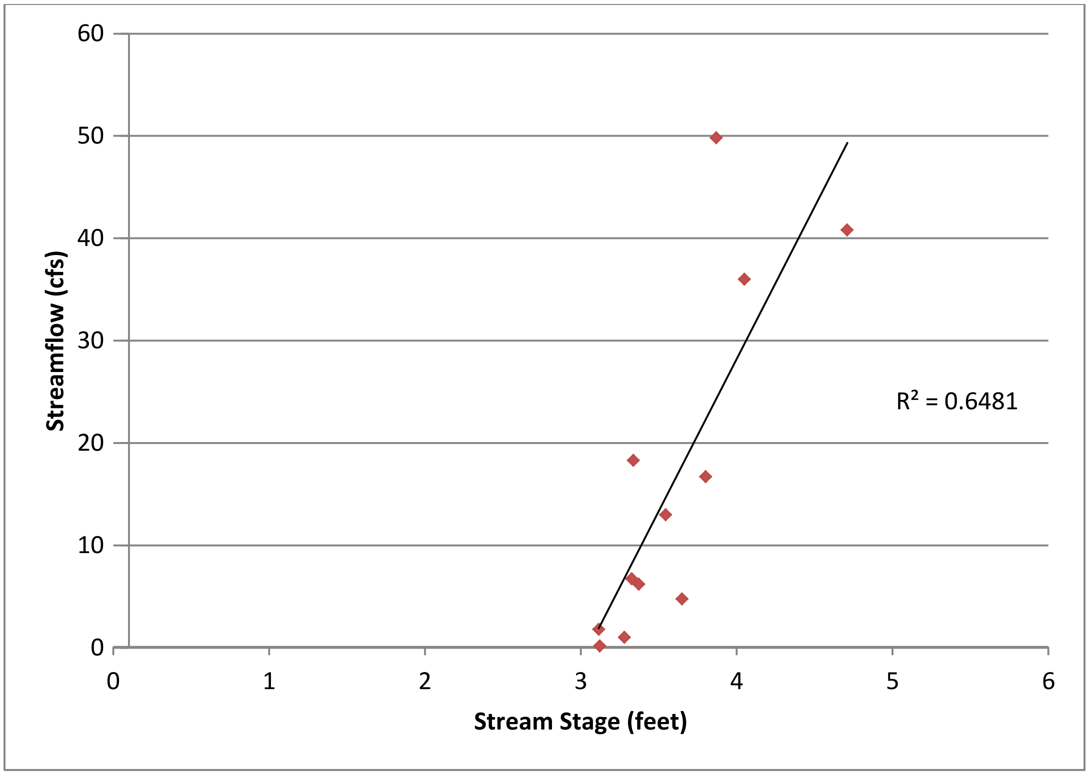


Figure 11. Cedar Creek stream stage and flow relationship.

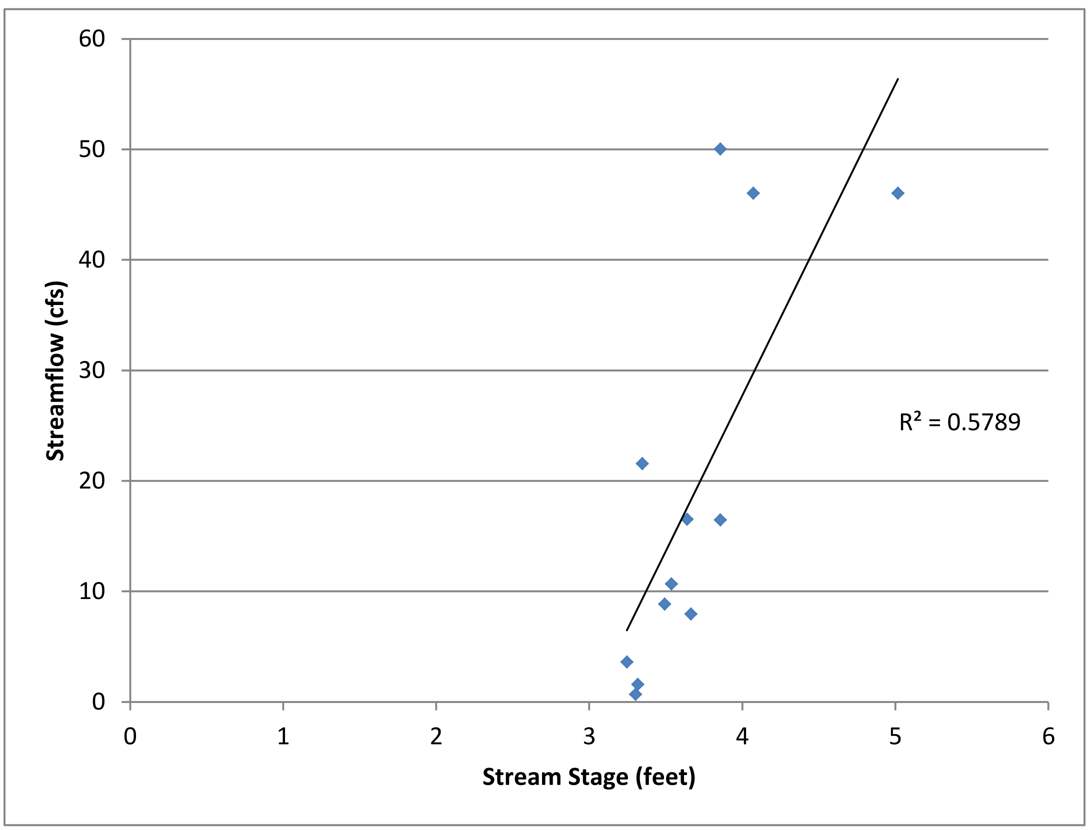


Figure 12. Fourth of July Creek stream stage and flow relationship.

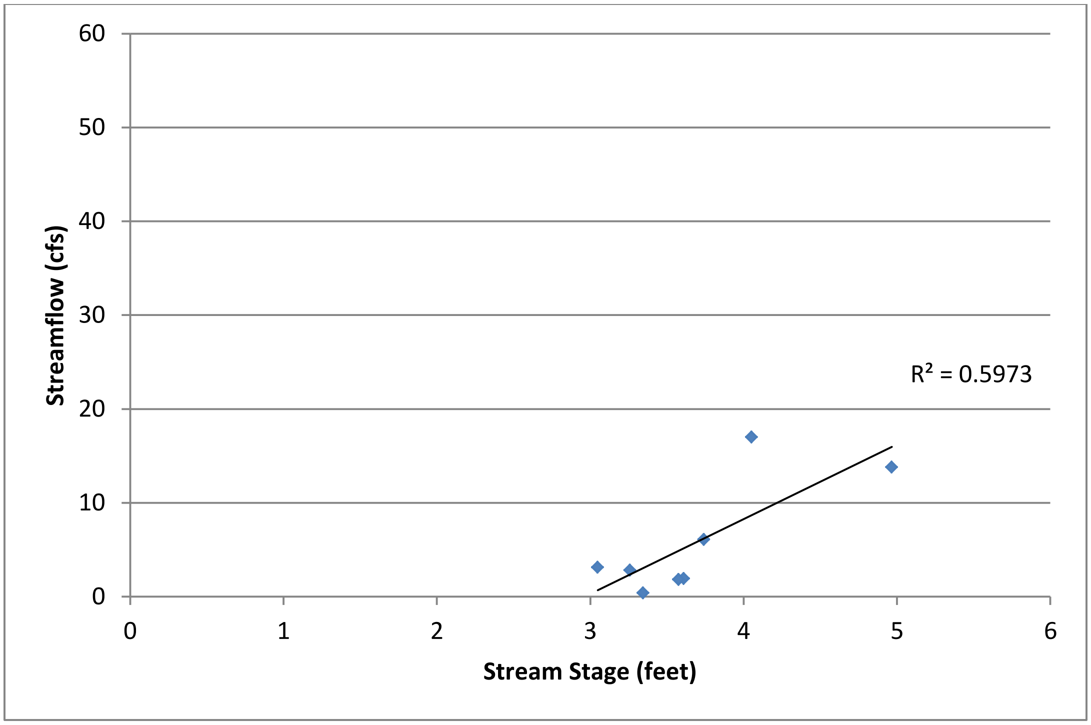


Figure 13. Fern Creek stream stage and flow relationship.

The equations derived from measured streamflow measurements and stream stage (Table 4) were used to convert stream stage to stream discharge for the entire period when data were recorded (Figures 14–16).

Table 4. Regression equations and R^2 values derived from stage and flow evaluation.

Stream	Equation	R^2 Value
Cedar Creek	$y = 29.75x - 90.78$	$R^2 = 0.6481$
Fourth of July Creek	$y = 28.17x - 85.001$	$R^2 = 0.5789$
Fern Creek	$y = 7.9705x - 23.612$	$R^2 = 0.5973$

Note: y = calculated ion concentration (mg/L)
x = measured specific conductivity (µS/cm)

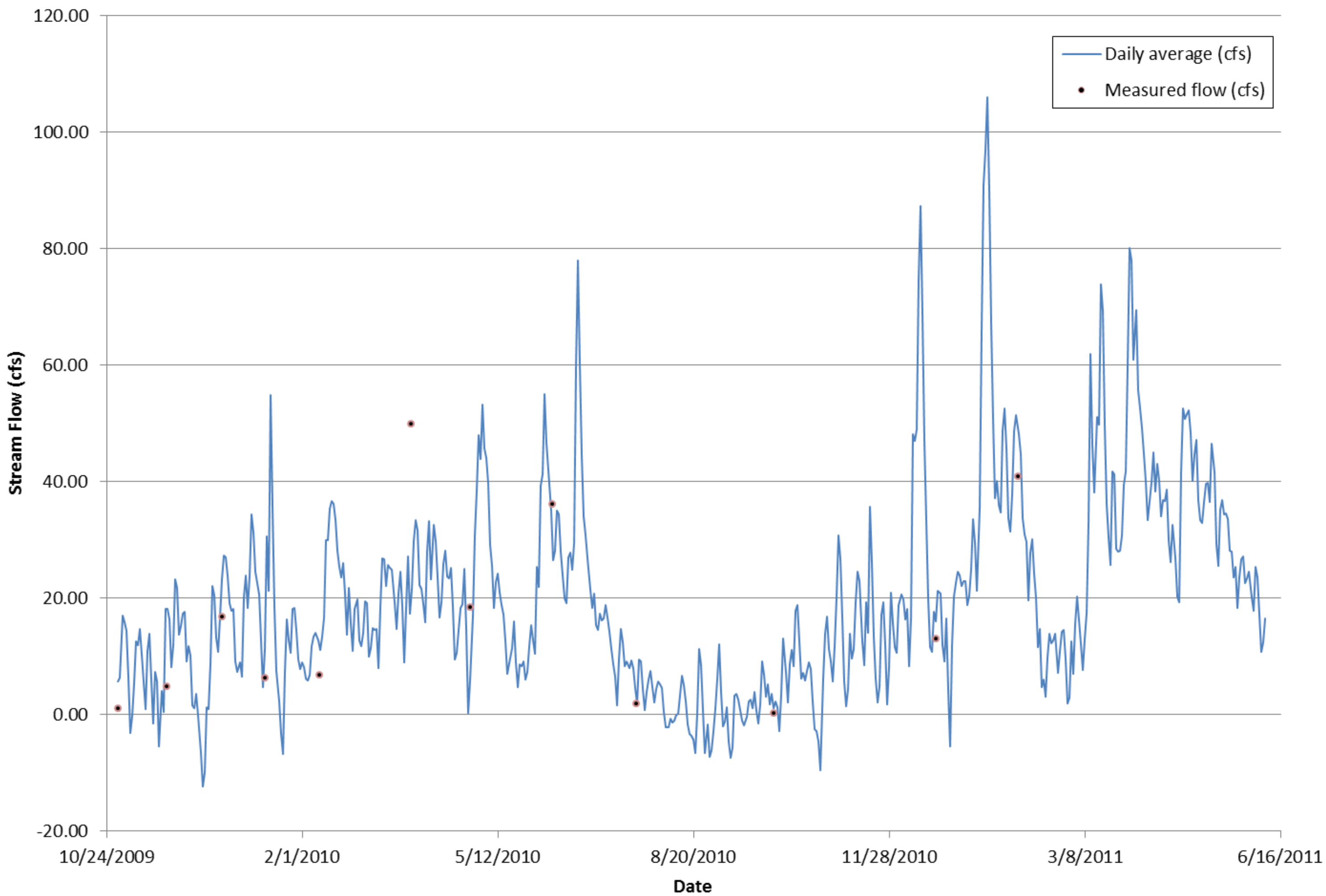


Figure 14. Cedar Creek calculated and measured streamflow.

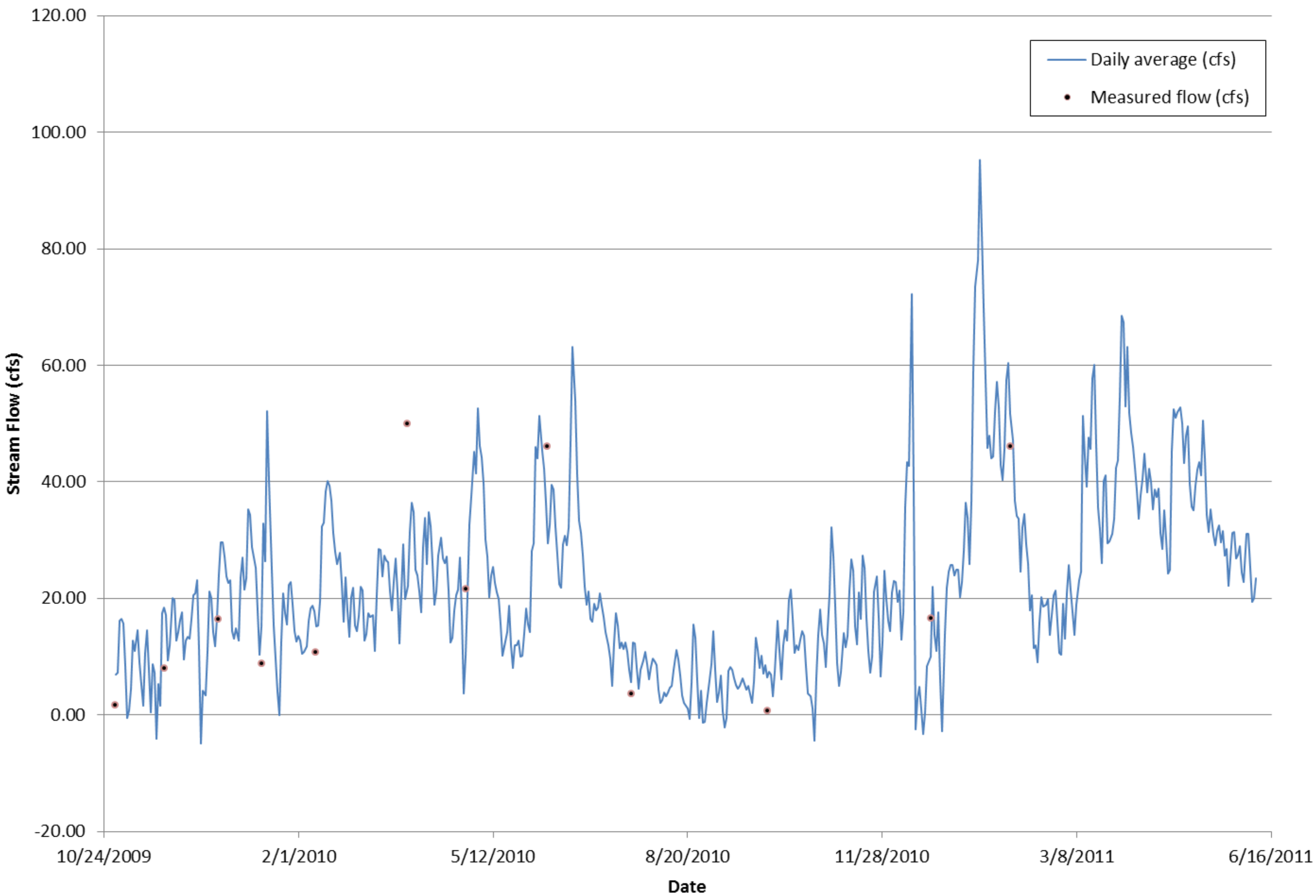


Figure 15. Fourth of July Creek calculated and measured streamflow.

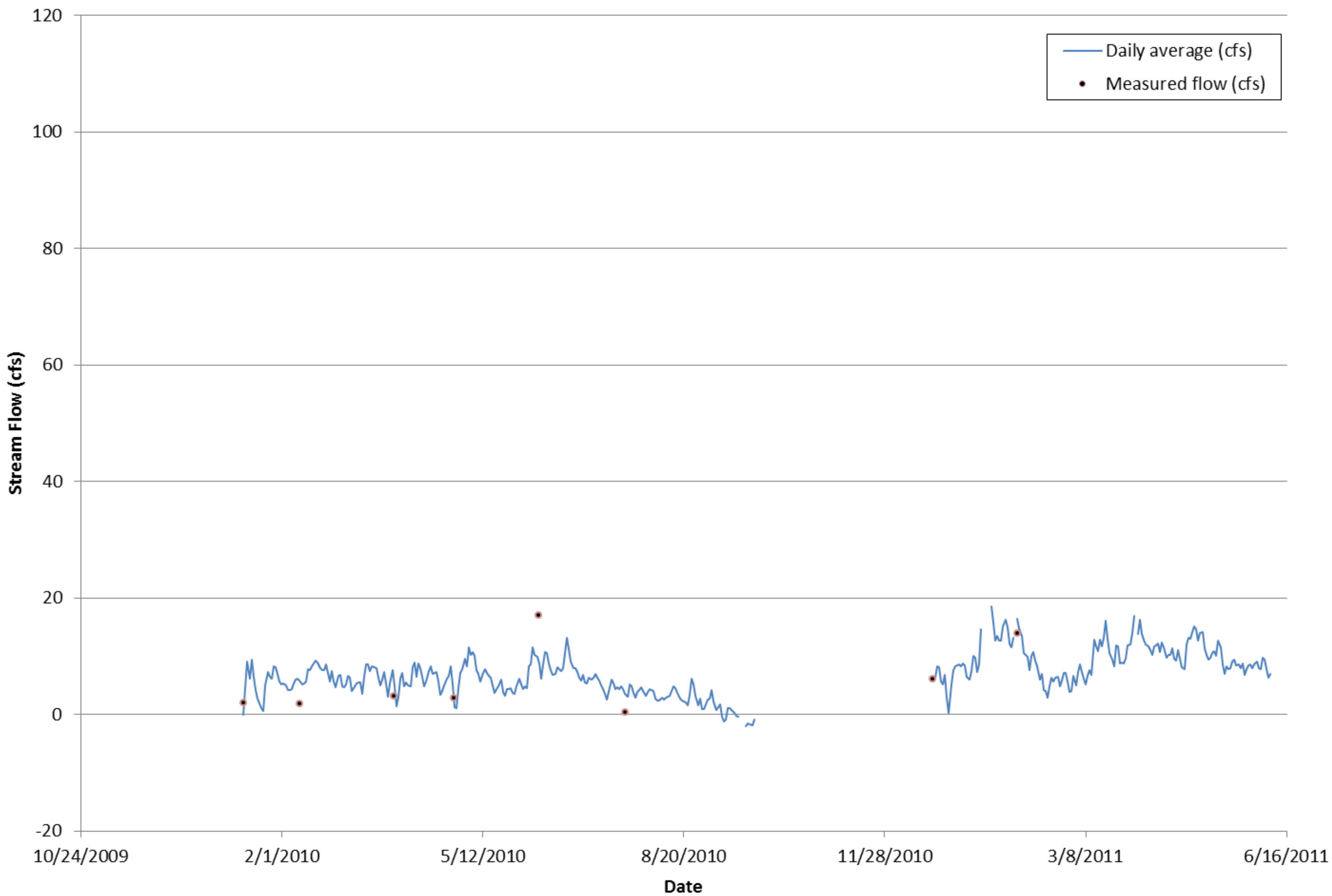


Figure 16. Fern Creek calculated and measured streamflow.

The method of calculating streamflow using a regression equation and continuous stage data from the data logger has limitations and can be improved. Calculated streamflow/stream stage values lower than those measured and used in the regression analysis are calculated to be less than zero. Reviewing the stream temperature and conductivity recorded for the days where flow was calculated to be below zero shows that the data logger was still covered by water. Cedar and Fourth of July Creeks are perennial streams while Fern Creek is ephemeral. The large portion of data missing in the Fern Creek graph is representative of the window when the stream was not flowing or the logger was not covered by water.

To strengthen the correlation between streamflow and stream stage in future monitoring efforts, a barometric pressure transducer can be placed near the stream data logger to collect site-specific barometric pressure. The pressure transducer in the data logger measures total pressure. Total pressure includes the pressure from the weight of the water above the data logger plus the barometric pressure above the water’s surface. Knowing the barometric pressure for each monitoring site would remove any error in the regression analysis associated with barometric pressure fluctuation.

Average barometric pressure recorded in Coeur d’Alene was used to try and strengthen the correlation between stream stage and streamflow but did not improve the correlation. The location of each site—each a significant distance from Coeur d’Alene and on opposite sides of a mountain pass—may help explain the lack of an improved correlation when removing barometric pressure recorded in Coeur d’Alene.

To calculate the amount of road salt (loads) within Cedar and Fourth of July Creeks, those streamflow values less than zero were defaulted to 0.1 cfs. One-tenth of a cubic foot per second is near the lowest possible measurement taken using the measurement methods of a surveyed cross-section, flow meter, and wading rod but still represents a perennial stream.

3 Sodium Chloride Loading Analysis

Knowing stream discharge during the winter driving season provides the opportunity to develop a road salt load within the stream. Using the two regressions (sodium chloride/specific conductivity and stream stage/streamflow) an estimation of the amount of road salt being carried through the system can be made. Knowing the amount of road salt in the stream and the amount applied to I-90 helps to evaluate the fate of the road salt in the environment:

- If the amount applied to I-90 is equal to the amount calculated in the stream, then it would be anticipated that a minimal amount is being attenuated to adjacent soils, assimilated by vegetation, or carried away by vehicles.
- If the amount applied to I-90 is much greater than the amount calculated within the stream, then it could be speculated that road salt is being attenuated to adjacent soil, assimilated by vegetation, or carried away by vehicles.
- If the amount applied to I-90 is less than the amount calculated within the stream, the elevated stream load may be attributed to unknown sources (house hold waste or other), residual from the previous year’s reaching the stream, stock pile contamination, or other.

Determining the background level of sodium chloride in Cedar and Fourth of July Creeks during the period influenced by road salt is difficult. Using the equations developed from the Fern Creek station and applying the recorded conductivity from Cedar and Fourth of July Creeks results in artificially high background concentrations. Because the equation relies on the measured conductivity to determine the sodium chloride concentration, the calculated background concentrations are inflated due to the elevated conductivity values associated with road salt. To help determine the natural background concentrations of sodium and chloride in Cedar and Fourth of July Creeks, the average conductivity values measured during the winter driving season in Fern Creek were used to calculate background sodium chloride loads and loads from road deicing (Table 5). Conductivity values (Figure 5) were reviewed to set the season beginning and ending dates to quantify the sodium chloride load associated with road deicing.

Table 5. Sodium chloride loads.

Stream Name	Season	NaCl total load (tons)	NaCl background load (tons)	NaCl Road Deicing (tons)
Cedar Creek	2010 (10/30/09–3/31/10)	260	18	242
	2011 (11/18/10–4/30/11)	248	38	210
Fourth of July Creek	2010 (10/30/09–3/31/10)	386	22	364
	2011 (11/18/10–4/30/11)	360	38	322

3.1 Idaho Transportation Department Road Salt Application

ITD tracks the amount of deicing chemical applied to Fourth of July Pass during the winter driving season (Figure 17). The years represent fiscal years, which span the winter months (July 1–June 30), so the totals per year represent the amount applied during the winter driving season. Two forms of road salt were applied to the interstate: solid salt and salt brine. The application of either the granular (solid) or brine solution depends on the condition of the roadway. Salt brine is used prior to a weather event to prevent the build-up of ice on the roadway; granular salt is used to break-up and remove ice and snow compacted on the roadway.

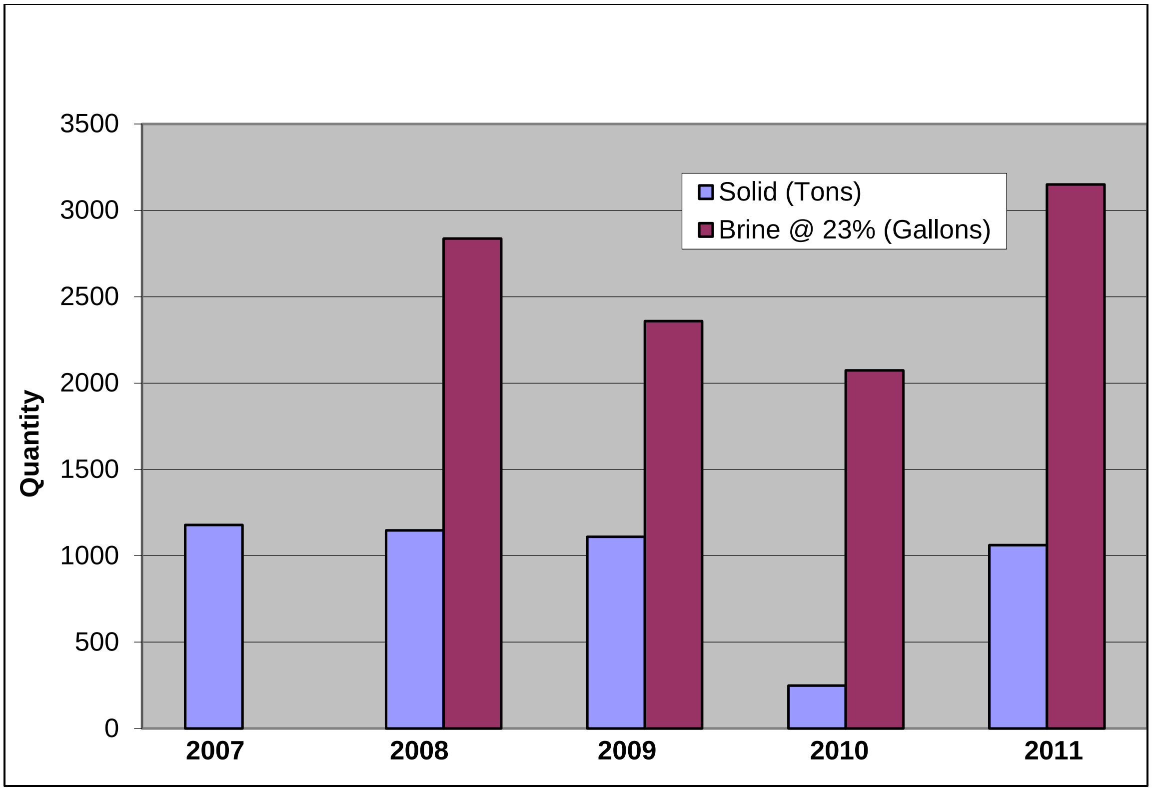


Figure 17. Fourth of July Pass road salt usage, fiscal years 2007–2011.

One gallon of 23.3% brine solution contains 2.29 pounds of salt. The total gallons of brine solution were multiplied by 2.29 to determine the amount of salt applied as brine. The total salt applied as solids and brine was calculated for each year (Table 6).

Table 6. Total amount of road salt applied to Fourth of July Pass.

Fiscal Year	Solid (tons)	Brine (23%) (gallons)	Brine NaCl (tons)	Total NaCl (tons)
2007	1,178	0	0.0	1,178.0
2008	1,148	2,837	3.2	1,151.2
2009	1,110	2,359	2.7	1,112.7
2010	249	2,073	2.4	251.4
2011	1,062	3,150	3.6	1,065.6

The total road salt applied to the roadway was compared to the calculated instream salt load (Table 7). The large discrepancy between the amount applied to the roadway and the amount calculated instream during the 2010 and 2011 winter driving seasons may be accounted for in the multiple equations used to calculate the instream load. Not knowing exactly when road salt applications halted, difficulty in determining the background load for Cedar and Fourth of July Creeks, and error in stream discharge contribute to the differences. The compounding amount of error has resulted in a large difference. The 2010 winter driving season was the least snowy winter during the study; however, the 2010 season had the highest recorded conductivity values and therefore the highest road salt concentrations.

Table 7. Total road salt applied to roadway and calculated combined instream load for Cedar and Fourth of July Creeks.

Year	Total Reported by ITD (tons)	Total Calculated Instream (tons)	Difference (tons)
2010	251	606	-355
2011	1,066	532	534

4 Data Evaluation

Excessive amounts of chloride can interrupt the osmoregulatory process of cells. Osmoregulation controls the osmotic pressure of an organism's fluids to maintain the constant balance of internal water content. Disrupting osmoregulation can cause the fluids to become too dilute or too concentrated causing death or slowed productivity.

The Clean Water Act requires states and tribes to adopt water quality standards to protect aquatic life from pollutants that can impact the aquatic environment. As discussed in 2008, Idaho doesn't currently have water quality criteria specifying sodium or chloride limits to protect aquatic beneficial uses. However, Idaho does have a toxic substances general surface water quality criterion (IDAPA 58.01.02.200.02), which may be applicable if road salt is determined to be impairing beneficial uses.

Reviewing the chloride water quality criteria established in other states and neighboring British Columbia gives an idea of how chloride concentrations along Fourth of July Pass might be impacting aquatic life (Table 8). Acute criteria typically represent a single sample maximum and are set at a level much higher than the chronic criteria. Most aquatic organisms can tolerate limited exposure to elevated chloride, but prolonged exposure leads to death or depressed productivity. The chronic standard is developed to be protective of aquatic organisms exposed to chloride for a prolonged period.

Table 8. Established water quality criteria for chloride.

Agency	Acute Criterion		Chronic Criterion	
	Value (mg/L)	**Explanation**	**Value (mg/L)**	**Explanation**
British Columbia Ministry of Environment[a]	600	Instantaneous maximum	150	Average of 5 weekly measurements taken over a 30-day period
Oregon Department of Environmental Quality	860	1-hour average concentration	230	96-hour average concentration
Washington Department of Ecology	860	1-hour average concentration not to be exceeded more than once every 3 years on average	230	4-day average concentration not to be exceeded more than once every 3 years on average
Minnesota Department of Natural Resources	860	Highest water concentration of toxicant to which organisms can be exposed indefinitely without causing chronic toxicity	230	Highest concentration of a toxicant in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality

[a] Government of British Columbia, Ministry of Environment, Environmental Protection Division

To evaluate the chronic chloride concentration water quality standard developed by the British Columbia Ministry of Environment, five date/ time combinations were randomly selected from the continuous data set within a 30-day window. Fourth of July Creek was chosen because it routinely exhibited the highest chloride concentrations and was therefore most likely to exceed chronic water quality criteria. To randomly select a date and time from the continuous data set, the following conditions were applied:

- Data collected from 4 p.m. to 9 a.m. were eliminated. The remaining time window best represents the time in which a sample would have been taken by department staff.
- The 30-day window began on November 23, 2009, the date when conductivity began to spike.
- A number was given to each hour data were collected and a random number generator was used to randomly select a date and time.

Dates within the specified time window were chosen and the calculated chloride concentration was recorded and averaged (Table 9).

Table 9. Random sample dates and times generated from Excel and average chloride concentration.

Run 1		Run 2		Run 3	
Date-Time	**Cl (mg/L)**	**Date-Time**	**Cl (mg/L)**	**Date-Time**	**Cl (mg/L)**
11/24/09-11:00	60	11/27/09-15:00	47	12/02/09-13:00	35
11/28/09-10:00	48	12/11/09-15:00	33	12/06/09-10:00	34
12/07/09-13:00	34	12/12/09-14:00	33	12/09/09-14:00	33
12/08/09-10:00	37	12/17/09-15:00	121	12/10/09-10:00	33
12/15/09-12:00	37	12/21/09-11:00	59	12/11/09-11:00	33
Average	**43.2**	**Average**	**58.6**	**Average**	**33.6**

Data collected during the study show chloride concentrations spiking and then sharply receding during the winter. The large spikes and sharp declines appear to average below the chronic criteria concentrations developed by other states. Maximum concentrations spiked above 230 mg/L during only two days during the 2009–2010 winter. Chloride concentrations did not spike above 200 mg/L during the 2010–2011 winter. The acute, single sample maximums developed by multiple states (i.e., 600 and 860 mg/L) were not exceeded during the years of monitoring (Figure 18).

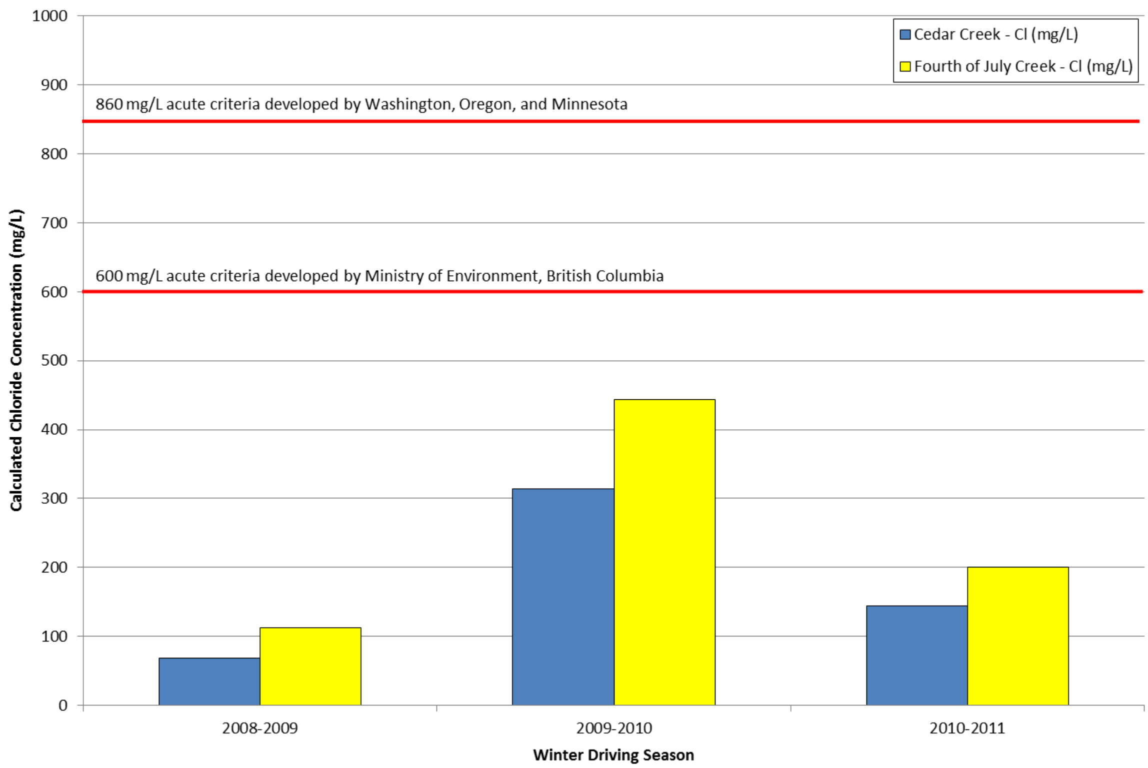


Figure 18. Maximum calculated chloride concentrations compared to established water quality criteria.

4.1 Current Water Quality Status of Cedar and Fourth of July Creeks

Fourth of July Creek (assessment unit ID17010303PN020_03) is listed as not supporting cold water aquatic life and salmonid spawning beneficial uses in *Idaho's 2010 Integrated Report* (DEQ 2011). The causes of impairment are physical habitat alteration and temperature. The nonsupport status was documented in 2006 by failing Beneficial Use Reconnaissance Program (BURP) scores. The cause of the physical habitat alteration impairment is channelization of the creek due to its proximity to I-90 and a series of flood control structures in place at the mouth of the creek.

Fourth of July Creek was originally listed for sediment in the 1990s when the use of traction sand on I-90 during winter months resulted in excess sediment and impairment of beneficial uses. Justification for delisting the sediment cause in 2010 was based on modeling completed in 1999 for the Coeur d'Alene Lake and River subbasin assessment and TMDL (DEQ 1999), channel substrate and streambank data collected in 2006 during BURP monitoring, cumulative watershed effects data collected in 2002 by the Idaho Department of Lands, and site visits in 2009–2010 (DEQ [forthcoming] 2012). These findings reflect the decreased use of traction sand during winter months along I-90.

Cedar Creek (assessment unit ID17010303PN030_03) is listed in *Idaho's 2010 Integrated Report* as not supporting cold water aquatic life and salmonid spawning beneficial uses (DEQ 2011). The causes of impairment are sediment and temperature. The basis for the nonsupport status was documented by failing BURP scores in 2006 at the mouth of Cedar Creek and by the Coeur d'Alene Lake and River subbasin assessment and TMDL five-year review (DEQ [forthcoming] 2012).

Similar to Fourth of July Creek, the original listing for sediment on Cedar Creek was during the 1990s when heavy traction sand was applied to I-90 adjacent to the creek. As stated in the 2008 road salt report, DEQ observed a significant reduction in fine sediment in Cedar Creek from 1996 to 2006, and this may be the result of the switch in 2003 from traction sand to deicers on I-90. However, unlike Fourth of July Creek, it was determined in the TMDL five-year review that excessive sediment may still be a cause of beneficial use impairment on Cedar Creek, so sediment remains listed.

This assessment was based on recent data collected by the Idaho Department of Lands and the US Forest Service (DEQ [forthcoming] 2012). The high road density (5.2 miles per square mile) in the upper watershed of Cedar Creek may be a source of excessive sediment as shown by Al-Chokhachy et al. (2010). Data from the US Forest Service indicated that hydrologic and land-use conditions may be a cause of excessive sand in low-gradient reaches and at the mouth of Cedar Creek (USFS 2008). It is uncertain what percentage of the excessive sand they observed was residual sand from road application or from an existing source of sediment to Cedar Creek. Additional instream evaluations are needed to answer this question.

The BURP scores reported in the 2008 road salt report were reported in error as showing support of beneficial uses (DEQ 2008a). Since the completion of the 2008 report, the BURP data collected in 2006 has been reassessed and indicate nonsupport of beneficial uses. The discrepancy occurred due to a misapplication of bioregion. Changing the bioregion from Central and Southern Mountain to Northern Rockies resulted in a change in the condition rating from support to nonsupport of beneficial uses (DEQ 2002). When this problem was corrected, the BURP scores changed from indicating support of beneficial uses to indicating nonsupport.

4.2 Drinking/Ground Water Impacts

This study only focused on the surface water impacts associated with road salt. Drinking water contamination is another factor to consider when evaluating environmental contamination from road salt and should be evaluated if ground water/drinking water contamination is suspected. In some parts of the country, ground water contamination from road salt has been well documented. Currently, the ITD is taking measures to reduce possible contamination by covering stockpiles, using computer assistance on applicator truck and plows, and limiting the amount of road salt applied.

The sodium chloride concentration in the surrounding ground water is unknown. Future monitoring efforts may consider monitoring ground water in the vicinity of Fourth of July Pass. The following information is given to provide reference to the possible health consequences of consuming too much salt.

Sodium is included on the US Environmental Protection Agency's (EPA's) drinking water contaminant candidate list. The list identifies contaminants which, at the time of the publication, are not subject to any proposed drinking water regulation, are known or anticipated to occur in public water systems, and may require regulation under the Safe Drinking Water Act (EPA 2011). A Food and Drug Administration publication states that most American adults tend to eat between 4,000 and 6,000 mg of sodium per day, "and therapeutic sodium restricted diets can range from below 1,000 mg to 3,000 mg per day" (Kurtzweil 1994). It lists the following nutrient guidelines for food labeling:

- Low-sodium: 140 mg or less per serving (or, if the serving is 30 grams [g] or less or two tablespoons or less, 140 mg or less per 50 g of the food)
- Very low-sodium: 35 mg or less per serving (or, if the serving is 30 g or less or two tablespoons or less, 35 mg or less per 50 g of the food)
- Sodium-free: Less than 5 mg per serving

In a National Inorganics and Radionuclides Survey conducted by EPA in the mid-1980s, about 75% of 989 water systems included in the study had concentrations of sodium less than 50 mg/L. Assuming that an adult weighing 150 pounds drinks 2 liters (about 8 glasses) of water per day, he or she would typically ingest less than 100 mg of sodium per day from drinking water. Based on this data, an 8-ounce glass would contain less than 12.5 mg of sodium, well within FDA's "very low sodium" category.

The highest measured sodium concentrations (from water samples) in Cedar and Fourth of July Creeks were 26.1 and 29 mg/L, respectively. The sodium concentrations calculated using the regression equation and recorded specific conductivity were much higher but lasted for only brief periods compared to the time monitored. Ground water concentrations may be less than those recorded in surface water due to the filtration provided by soil and surrounding geology.

It is important to note that sodium is an essential nutrient. The Food and Nutrition Board of the National Research Council recommends that most healthy adults need to consume at least 500 mg/day but that sodium intake be limited to no more than 2,400 mg/day.

5 Conclusion

Water quality data collected in streams adjacent to I-90 in north Idaho during the last half of the 2008 winter and continuously from October 2009 through June 2011 show elevated sodium and chloride concentrations during the winter driving season. The application of road salt to improve winter driving conditions elevates instream sodium and chloride concentrations. During the same period, sodium and chloride concentrations were monitored in a stream not impacted by highway runoff. The concentrations of the nonimpacted stream remained consistently low and did not fluctuate during the winter.

The two streams most impacted by highway runoff (i.e., Cedar and Fourth of July Creeks) are not supporting beneficial uses due to excess temperature and habitat alteration. Increases in chloride have been shown to be detrimental to aquatic life in high concentrations or moderate concentrations for a prolonged period. Idaho currently does not have water quality criteria regulating the concentration of instream chloride, but neighboring states have adopted chloride criteria to protect aquatic life. Chloride concentrations were compared to criteria from neighboring states and were determined to be below their criteria.

Beneficial use monitoring should continue in Cedar and Fourth of July Creeks. Routine monitoring will help to develop water quality trends and help managers determine the best course of action to protect winter travelers and cold water aquatic life.

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Appendix A. Idaho Transportation Department Winter Operations

The following section describes how ITD maintains safe winter driving conditions using salt. The description was provided by ITD staff.

> The best way to describe ITD's winter storm response is to see it as a major reduction in sand use, not an increase in salt. The amount of solid salt being used is virtually the same as in past winters. The Department has used a salt/sand mixture as part of its winter maintenance for many years, and about 20 years ago began using liquid salt solutions of magnesium chloride on the roadways. The District switched to a salt brine solution about 5 years ago, in order to increase efficiency and lower costs. We will continue to use these two primary tools for specific applications as part of our snow and ice removal operations. The type of salt we use for both straight salt and salt/sand applications is sodium chloride, more commonly called table salt.
>
> In 2004, District One began using straight salt on certain areas of the interstate by eliminating the sand in the mixture. The test involved using about the same amount of salt, but a lot less sanding material, and doing an equal or better job of clearing the roadway. Eventually, the use of straight salt was expanded to cover the five northern counties.
>
> **The District has addressed some of the concerns area citizens have expressed.**
>
> **Salt application and corrosion to vehicles.** ITD has used salt mixed into the sanding material since the 1960s. The salt increases the effectiveness of the sanding material. Additionally, it keeps stockpiles of sand from freezing solid; otherwise, loading equipment could not dig into the stockpile to fill the trucks. Typically, the amount of salt in the sand used in the Coeur d'Alene/Post Falls area was about 15% by volume.
>
> Application rates for straight salt are considerably less than that for sanding material. ITD has learned that one truckload of straight salt would treat the same length of roadway as six truckloads of the salt/sand mixture. In other words, the same amount of salt was used in both applications, but we were using a lot less sanding material.
>
> For liquid applications, the amount placed on the roadway varies with the purpose of the application. For anti-icing applications, liquids are applied just before the storm event at a rate of 25-gallons per lane mile. The Department typically uses this solution as a pretreatment prior to storms for breaking the ice-to-pavement bond. This greatly decreases snow removal time and can prevent black ice from forming. Occasionally, liquids are applied directly on snow and ice to speed melting. These applications are at 35-gallons per lane mile.
>
> For solid applications, ITD applies salt behind the snow plow to help melt the remaining snow and ice. These applications are typically at 130-pounds per lane mile, with about 200-pounds per lane mile in the mountain passes.
>
> The unfortunate consequence of using salts on the highways is corrosion. It has been a problem for many decades, and various solutions have been attempted. For metal roadway features, bigger sizing and coating of reinforcement steel in concrete structure and metal pipe is used. Automobile manufacturers now regularly apply protective coatings. Transportation agencies have experimented with buffering agents added into the salt, which to date, has not proven very successful.
>
> Another corrosion issue is the effect of different salts on various metals. Many transportation agencies use magnesium chloride or calcium chloride salts, which are relatively less corrosive to iron and steel, but very corrosive to aluminum and copper. Damage to auto body panel is less, but damage to wheels, engines, and electrical items is common. ITD uses sodium chloride salt, which is more corrosive to iron and steel, but has little impact on aluminum and copper. Because the auto industry now coats modern vehicles, this corrosion impact is reduced.

The best method available today to minimize corrosion is the careful and minimal use of salt. The application rates used by ITD are far below that commonly used in the Mid-Western States. These States commonly use application rates of 600-pounds to 1500-pounds per lane mile. This is done because the winter temperatures they experience are colder, and there is a need to immediately clear the roadways with very high traffic volumes found in the metropolitan cities. Unfortunately, modern research has shown that this 'more is better' approach is not effective and is wasteful. At ITD, we take advantage of lessons learned, and have found that we can be very effective with far less material. The weather in northern Idaho is more temperate, with heavy, wet snow that responds the best with the salt program.

The condition of the trees along state highways, and other highways across the Pacific Northwest, is often a temporary, seasonal occurrence that is a result of winter roadway maintenance. The condition is referred to as needle browning by the Transportation Agencies of Washington, Montana, and Idaho. Needle browning is the result of two different events that occur during snow removal activities.

The first event is the physical abrasion of the snow plume coming out of the plow truck or blower. The snow is launched out of a plow at speeds over 100 miles per hour. The snow is unusually icy and water laden, and often has foreign material ranging from dirt to objects that have fallen off vehicles. The force of the blast will damage the needles, and if the tree is close enough to the roadway, long term damage to branches will occur as the buds on the tree are stripped off.

The second event is the snow coming off the plows and blowers contains salts that are used during snow removal. When the salts contact and stick to the needles, the moisture in the needles is drawn out. In both events, the needles brown prematurely through dehydration.

Pine species have much less resistance to these effects than the fir and spruce species. So if pines are the predominate species along the roadway, the visual impact is far more apparent. The brown needles will fall off the tree once the new annual growth emerges. Typically by mid-July, the trees are green again.

The Pacific Northwest states of Washington, Oregon, Idaho and Montana have experienced this phenomenon, and have consulted other agencies, including U.S. Forest Service and the Department of Environmental Quality. There appears to be little concern over the long term health of the pine trees. They view the browning as a temporary event.

There is also browning of trees due to infestations and disease. This occurs well past the roadway and can be distinguished separately from damage due to highway operations.

It should be noted that those trees very close to the pavement are at the greatest risk. They also present the greatest problem for ITD to manage. Where the trees are very close, the typical situation is that ITD occupies an easement for the roadway, and as such, does not own the land or the trees. Trees close to the highway hide wildlife and other roadway hazards. Trees leaning onto the roadway threaten clear egress. A large tree can be life threatening when it is struck by a vehicle. While we can remove hazard trees in these locations, if the tree has a marketable timber value, ITD must coordinate with the owner on how to deal with the tree so they can be compensated. The legal definition of a hazard tree is vague, which complicates simple removal. Also, trees grow quicker and in greater numbers than ITD resources have to remove them, although ITD has received significant help through outside agencies.

Environmental considerations of using straight salt vs. sanding material on state highways. Soil tests conducted by ITD have confirmed that the salt application process is environmentally safe when Best Management Practices are applied. The Department does not anticipate any increase in accumulation because the amount of salt the Department uses is about the same rate that has been used in the past. We will continue to conduct soil tests as part of our ongoing maintenance operations.

Decreasing the use of sanding material has the potential for leading to secondary environmental improvements. By decreasing the use of sand, the dust on the roadways is significantly reduced, and air quality is improved. Our efforts in the past to reduce the use of sanding material has made great strides in improving air quality, and the use of straight salt applications should make further improvements. The reduction in the use of sanding material also minimizes other issues with residual sand that can be difficult to clean up in the spring.

The Idaho Department of Environmental Quality has conducted a multi-year study investigating environmental quality of water bodies along I-90. This study showed that salt concentrations in these water bodies never reached thresholds dangerous to plants, wildlife, or humans. Small increases of salt concentration during the winter were temporary and were flushed with the spring runoff.

The sanding gravel once used by ITD caused great loss of fish spawning beds. The grit would choke off these spawning beds, killing the fish eggs. Because this practice is no longer extensively used by the Department, these spawning beds are returning to their original vitality. In the past, ITD needed to annually contract $550,000 to remove the sanding material from the roadways during the spring to meet air quality standards. This expense was greatly reduced to about one fifth of this amount, with the need being mostly in the Coeur d'Alene Superfund Site.

There does not seem to be a correlation between the number of animal/vehicle collisions and salt usage. There are significant migratory corridors throughout northern Idaho, and many of these corridors conflict with the state highway system. Animal/vehicle crashes are inevitable; however, there is no quantified data showing that salt usage has significantly increased these conflicts. For example, a report by the Idaho Fish and Game Department in 2008, rated SH-57 a low priority wildlife linkage corridor for animal/vehicle crashes (5-20 animals, deer and moose). During the past five years, there have been a total of 145 crashes, and of these, 34 accidents involved animals on SH-57 (MP 1 to MP 37). The animal/vehicle accidents involved 54 people, five injuries and no fatalities.

Costs for snow removal will decrease per lane mile in areas using straight salt. Placing one load of salt instead of six loads of sanding material is a big savings on personnel, equipment, and fuel costs, as well as time. These savings mean that our snow removal equipment and personnel can move on to lower priority routes sooner, thus improving the level of service across the entire federal and state highway system in the Idaho Panhandle.

One might ask, if straight salt works as well as ITD says it does, why not eliminate the sanding material altogether? Straight salt is not a universal cure-all. When temperatures are extremely low (below 17 degrees Fahrenheit), salt is far less effective at melting snow and ice. If snow fall is accumulating quickly, salt alone is not enough to improve traction, and sanding material without salt will be used on rare occasions.

To meet Performance Standards for highway operations, ITD is utilizing its Roadway Weather Information Stations (RWIS) to grade the winter effort of the road crews. The RWIS's automatically record the 'grip' of the roadway, which diminishes during snowy and icy conditions, but improves with effective snow and ice control. This grading system has been put in place for this winter season. To date, District One is scoring very well. The District is hoping to expand this system and implement Auto Vehicle Locations (AVL), which will enable us to directly correlate our performance with our resources, thereby optimizing both.

Our goal is to always research and utilize the maintenance methods that best serve the traveling public. We want to make travel for you and your family as safe as possible, and at the same time preserve the investment we've made in our highways and vehicles, and in the great environment we are fortunate to enjoy.

The District will continue to work with the Department of Environmental Quality (DEQ) to monitor soil and water quality. We will likely expand this program as needed.

If you need any further information about winter maintenance operations in District One, please contact the District office at 208-772-1200. We can provide additional crash data, DEQ reports and other studies/reports on winter maintenance practices in northern Idaho.